Comparison of Calf Housing Types and Tympanic Temperature Rhythms in Holstein Calves[1,2]

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ABSTRACT

During fall, 30 Holstein calves were randomly assigned to three housing treatments from birth to weaning: conventional wooden hutches, enclosed molded polyethylene domes, and thermomolded opaque polymer hutches with ridge-top ventilation systems. The wooden and polymer hutches had outdoor pens. Fifteen calves, 5 in each housing type, were fitted with portable data loggers to record ambient (calf microclimate) and tympanic temperatures. Additional data collected included weekly girth, BW, and feed intake; blood samples were collected within 24 h of birth and at weaning (8 wk); and behavioral observations were made at 1, 4, and 7 wk of age. Polyethylene domes had the warmest microclimate, followed by wooden and polymer hutches. Feed intake, growth measurements, blood physiology, and behavior were unaffected by housing type. Diurnal tympanic temperature rhythms of neonatal dairy calves in this study were monophasic: maximums were at 1200 to 1700 h, and minimums were at 0600 to 0900 h. Computed fractal dimensions of tympanic temperature by week indicated a gradual diminishing of stress as the calves became older and acclimated to their environment. This objective characterization provides a basis for further evaluation of physiological stress and a means of improving environmental management.
(**Key words**: calf housing, tympanic temperature, fractal dimensions)

INTRODUCTION

The environment affects the exposure to, infection by, and perpetuation of disease in calves and resultant morbidity or mortality (1). Environmental extremes of cold or heat decrease disease resistance in dairy calves (5). Susceptibility of the calf to disease is dependent on a calf's passive immunity, its innate resistance to infection, the burden of infection in the environment, and the nutritional quality of the diet. Reported calf death losses have ranged from 7 to >20% (1, 13). Under good management conditions, rate of neonatal calf mortality (the number of calves that are born alive but die between 24 h and 28 d) should not exceed approximately 3% (18). During this period, septicemia and enteric disorders are the main causes of death. Mean mortality rate (heifer deaths prior to weaning per number of heifers born alive) was 14.7% in one study (6), and calf mortality from birth to 3 mo was 6.5% in another study (13).

Received February 22, 1994.
Accepted November 14, 1994.

[1]This research was conducted in cooperation with the Utah Agricultural Experiment Station and the Utah State University Animal, Dairy, and Veterinary Sciences Department. Approved as Utah Agricultural Experiment Station Journal Paper Number 4497.

[2]Mention of a trade name does not imply an endorsement or recommendation by the USDA or Utah State University over similar companies or products not mentioned.

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Dairy managers significantly underestimated calf mortality rates at 2 to 5% and tended to underestimate economic losses (6). A calf death involves the loss of its production potential and the reproductive period of the dam (2). The disparity between actual and estimated calf mortality rates may reflect the failure of producers to keep accurate calf records on calf mortality (6).

Improved environmental management may alleviate losses (5). However, housing calves individually prior to weaning did not reduce mortality (13). In many California dairies, calves are grouped prior to weaning, and individual calves are often housed in wooden hutches (6). Housing type may not affect growth or survival rates (14, 22), even though individual calf housing has been popular for more than 20 yr. Such housing provides environmental protection, helps prevent spread of disease, and facilitates the detection and treatment of sick calves. The addition of suitable bedding and a draft-free environment can reduce the direct stress of cold on even the young calf to negligible proportions (23).

Cattle are homeotherms with a complex thermoregulatory system. They maintain thermoneutrality through adjustments in behavior, internal heat production, heat transfer from the central core to the surface, heat loss from the surface, and evaporation (24). Short-term fluctuations in cattle body temperature occur because of metabolic processes, physiological changes, and environmental stressors. Three primary sites—rectum, vagina, and ear canal adjacent to the tympanic membrane—are used for accurate measurement of internal body temperature of cattle (25). Tympanic temperature is most responsive to external stimuli (25) and is an acceptable index of hypothalamic temperature (11). Tympanic temperature provides a means of objectively measuring stress in cattle, thus improving the characterization of stress (8).

The objectives of this study were to compare the effects of three types of individual calf housing on growth, physiology, and behavior during the fall. We also examined tympanic temperature rhythms in neonatal Holstein calves and examined the use of computed fractal dimensions as a possible means of identifying stress in calves.

MATERIALS AND METHODS

Thirty Holstein calves were randomly assigned to one of three housing types from birth to weaning. The study took place over a 15-wk period during the fall (September to December). We compared conventional wooden hutches (1.2 × 2.4 × 1.2 m high) with an outdoor pen (1.2 × 1.8 m), enclosed molded polyethylene domes (2.2 diameter × 1.5 m high; Poly Dome, Litchfield, MN), and thermomolded opaque polymer hutches (1.4 × 2.2 × 1.3 m high) with ridge-top ventilation systems (Hampel Corp., Germantown, WI) and an outdoor pen (1.2 × 1.8 m).

Of the 30 calves, 15 (5 in each housing type) were randomly assigned to be fitted with portable data loggers to record tympanic temperature. Treatments (combination of data logger and housing) were randomized within blocks (calves). During the 8 wk that each calf was on the study, tympanic temperature probes were replaced weekly in alternate ears of the calves when temperature data were downloaded to computers. Microclimate (ambient temperature) was measured by thermistor sensors located in the data loggers, which measured internal temperature of the data logger. Tympanic temperature probes placed in the ear canal next to the tympanic membrane were held in place by prosthetic foam. The data loggers were enclosed in an aluminum case, the edges of which were sealed with silicone gel, and held in place on the calf's back with a webbed belt. The portable data loggers and tympanic probes were commercial units (Mini-Mitter Co., Inc., Sunriver, OR) that were similar to those described by Hahn et al. (10). Temperature resolution of the tympanic recording system was .04°C. Calves received colostrum for three feedings and 2 L of whole milk twice daily; water, grain, and hay were offered for ad libitum intake. Straw bedding was replaced or added as needed. Data collected included tympanic and ambient temperatures recorded at 5-min intervals; weekly girth, BW, and feed intake; physiological blood parameters within 24 h of birth and at weaning at 8 wk; and hourly behavioral observations (from 0700 to 1900 h) at 1, 4, and 7 wk of age.

Initially, the experimental design was a randomized block with a 2 × 3 factorial treatment arrangement with repeated measurements (i.e., split-plot) in time. Main treatment effects were

TABLE 1. Calf housing microclimate from September to December.

Housing type	Ambient temperature		
	Mean	Maximum	Minimum
	(°C)		
Polymer hutch	13.23	26.28	4.14
Polyethylene dome	17.31	32.72	6.30
Wooden hutch	14.38	29.28	4.96

data logger or no data logger and type of housing. A split-plot model was used with the combinations of data logger and housing as the whole-plot treatment, and week was the subplot treatment. Because the presence of the data logger did not have any effects on the parameters measured, the statistical model used was

$$Y = \mu + B_i + H_j + E_{ij} + W_k + S_{ik} + HW_{jk} + V_{ijk},$$

where B = the block effect (calf); H and W = the effects of housing and week, respectively; and E, S, and V = the error terms of the split-plot model. Data were analyzed using the general linear models procedure of SAS (19).

RESULTS AND DISCUSSION

Polyethylene domes had the warmest microclimate, followed by wooden hutches and polymer hutches (Table 1). Lamb et al. (16) noted that the temperature of polyethylene domes tended to average 5 to 10°C higher than wooden hutches during a year-long study. Figures 1, 2, and 3 show typical temperature rhythms and microclimates for the different types of housing. Differences were evident for ambient temperatures between the different housing types, and the polyethylene domes had higher ambient temperature during the day than did the other housings. Tympanic temperatures of neonatal dairy calves were monophasic: maximums were at 1200 to 1800 h, and minimums were at 0600 to 0900 h. Hahn (7) reported that tympanic temperature in livestock that are fed for ad libitum intake usually showed a monophasic rhythm; maximums were near midnight and minimums were in late morning in moderate thermal conditions (.5 to 1.2°C). For lactating cows in Israel (3), maximum tympanic temperatures occurred at about 1800 h during winter and summer, and minimum tympanic temperatures occurred between 0900 and 1500 h during winter and between 0300 and 0600 h during summer.

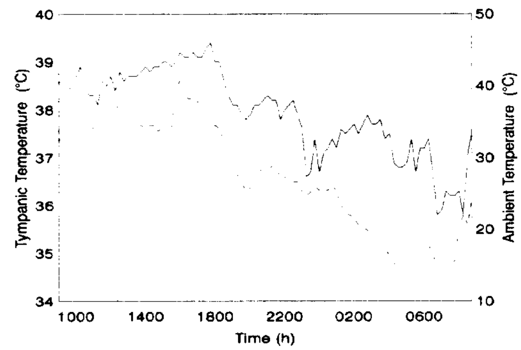

Figure 1. Tympanic (—) and ambient (--) temperatures of calf 7556, September 12, wk 2, housed in a polymer hutch. The ambient temperature was measured within the data logger strapped to the calf and reflects the microclimate as influenced by the thermal environment and heat loss by the calf. Minimum, maximum, and mean tympanic temperatures were 36, 39, and 38°C, respectively. Minimum, maximum, and mean ambient temperatures were 13, 41, and 28°C, respectively.

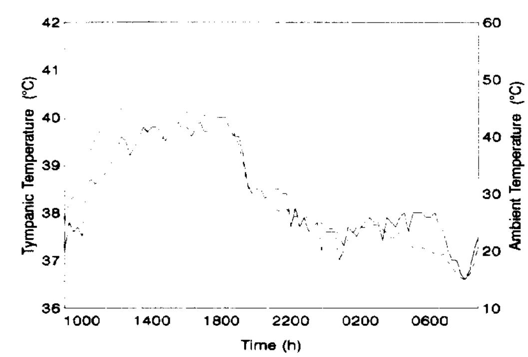

Figure 2. Tympanic (—) and ambient (--) temperatures of calf 7603, September 12, wk 2, housed in a polyethylene dome. The ambient temperature was measured within the data logger strapped to the calf and reflects the microclimate as influenced by the thermal environment and heat loss by the calf. Minimum, maximum, and mean tympanic temperatures were 37, 40, and 38°C, respectively. Minimum, maximum, and mean ambient temperatures were 15, 45, and 31°C, respectively.

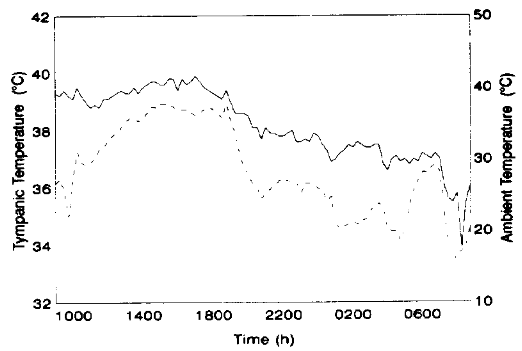

Figure 3. Tympanic (—) and ambient (--) temperatures of calf 7605, September 12, wk 2, housed in a wooden hutch. The ambient temperature was measured within the data logger strapped to the calf and reflects the microclimate as influenced by the thermal environment and heat loss by the calf. Minimum, maximum, and mean tympanic temperatures were 30, 40, and 38°C, respectively. Minimum, maximum, and mean ambient temperatures were 15, 38, and 28°C, respectively.

During summer in Arizona, maximum rectal temperatures of dairy cows occurred from 1400 to 1800 h, and minimum temperatures occurred from 0400 to 0900 h. In constant thermoneutrality, the maximum rectal temperatures of nonlactating dairy cows occurred between 1700 and 2400 h. Maximum rectal temperatures occurred between 1500 and 2000 h in cyclic thermoneutral conditions, between 1300 and 2300 h in cyclic conditions simulating Phoenix, Arizona, and between 1600 and 2300 h in cyclic conditions simulating Atlanta, Georgia (21). Body temperature rhythms in feed-restricted animals appear to be strongly associated with feeding patterns, but body temperature appears to be monophasic in animals fed for ad libitum intake and not experiencing stress (8).

Environmental stressors can disrupt body temperature rhythms. Hahn et al. (8) used fractal analysis to analyze stress of cattle that was caused by elevated ambient temperatures and to determine stress response thresholds. Computed fractal dimensions measured the roughness of the process. The fractal dimensions of tympanic temperature measured the thermoregulatory variations during the circadian rhythm and provided a basis for objectively characterizing levels of stress (8). An interpretation of fractal dimensions (D) to determine animal stress has been suggested by Hahn et al. (10), based on analyses of data collected from feeder cattle in nonstressor (thermoneutral) and stressor (hot) environments (8): $\geq$1.7, no stress; $1.6 \leq D < 1.7$, slight stress; $1.5 \leq D < 1.6$, mild stress; $1.4 \leq D < 1.5$, moderate stress; $1.3 \leq D < 1.4$, marked stress; and $1.2 \leq D < 1.3$, severe stress. Although the specific boundaries between stress categories need further verification, fractal dimensions computed from tympanic temperatures of calves in this study indicated that this analytical technique also has application for evaluating stress of neonatal calves during cool autumn weather. Table 2 s hows that fractal dimensions fluctuated somewhat during the first 5 wk of life, ranging from 1.40 (wk 2) to 1.54 (wk 3), and then stabilized at about 1.55 from wk 6 through 8. These values indicate a generally moderate level of stress initially, lessening to a mild level as the calves became older and better acclimatized. The moderate levels of stress indicated for wk 1 and 2 were associated with slight decreases in mean BW (45 kg at birth vs. 44 kg at wk 1 and 2); by wk 3, the BW was 46 kg and steadily increased thereafter.

The Utah State University clinical veterinarian examined calves within 24 h of birth and at weaning (8 wk). Examinations included a thorough physical examination and blood sampling via venipuncture. Complete blood cell counts were conducted at Logan Regional Hospital (Logan, UT). The number of medical treatments required by each calf was also recorded: the maximum was 2, and the mean number was .35, for calves in each type of housing. Housing had no affect on blood parameters, heart rate, or rectal temperature (Table 3). Differences existed in heart rate, respiration rate, lymphocytes, erythrocytes ($P < .0001$), and leukocytes ($P < .005$) at different ages (Table 4). Scibilia et al. (20) noted that respiration rates of newborn calves were affected by environmental temperature. When calves were monitored for 24 and 144 h after birth (18), respiration rates fluctuated an average of about 44/min ± 4 ($\overline{X}$ ± SE), and heart rate and rectal temperature decreased from birth to 12 h, but rectal temperature tended to increase from 60 to 96 h. Kurz and Willett (15) noted considerable variation among calves, especially in heart and respiration rates and counts for leukocytes and lymphocytes. The variation in the number of circulating leukocytes results from several factors, including muscular activity and the

TABLE 2. Fractal dimensions of the tympanic temperature of neonatal calves from data recorded at 5-min intervals from September to December.

	Mean fractal dimension	Data set[1]	Interpretation[2] of stress
		(no.)	
Week			
1	1.44	2	Moderate
2	1.40	6	Moderate
3	1.54	8	Mild
4	1.45	7	Moderate
5	1.44	11	Moderate
6	1.56	13	Mild
7	1.53	13	Mild
8	1.55	12	Mild
Housing			
Polymer hutch	1.50	25	Mild
Polyethylene dome	1.52	25	Mild
Wooden hutch	1.51	22	Mild

[1]Number of weekly calf data sets used for computing fractal dimension.

[2]Based on Hahn et al. (9).

TABLE 3. Mean calf physical data for different housing types.

	Housing type			
	Polymer hutch	Polyethylene dome	Wooden hutch	SE
Rectal temperature, °C	38.81	38.99	38.67	.14
Heart rate, beats per min	112.60	110.50	119.20	3.79
Respiration, breaths per min	48.15	53.30	49.80	3.66
Hemoglobin, gl/dl	10.52	11.27	12.52	.64
Erythrocytes, $\times 10^6/\mu l$	5.24	5.77	5.81	.33
Leukocytes, $\times 10^3/\mu l$	20.19	17.59	25.06	4.76
Lymphocytes, %	42.11	38.36	34.45	3.08

TABLE 4. Mean differences in calf physical data that were due to age at sampling.

	Age			
	Within 24 h of birth		8 wk of age	
	$\overline{X}$	SE	$\overline{X}$	SE
Heart rate, beats per min	134.87[a]	3.63	93.33[b]	3.63
Respiration, breaths per min	62.53[a]	2.99	36.33[b]	3.23
Leukocytes, $\times 10^3/\mu l$	29.86[c]	3.63	13.32[d]	4.41
Erythrocytes, $\times 10^6/\mu l$	6.43[a]	.26	4.78[b]	.32
Lymphocytes, %	23.93[c]	2.72	52.68[b]	2.87

[a,b]Means in the same row with different superscripts differ ($P < .0001$).

[c,d]Means in the same row with different superscripts differ ($P < .005$).

TABLE 5. Percentage of time spent (from 0700 to 1900 h) by week and housing type in neonatal dairy calves.

	Inside housing	Outside housing	Lying	Standing
	(% of time)			
Week				
1	93	7	83	17
4	89	11	68	32
7	88	12	59	41
Housing				
Polymer hutch	86	14	68	32
Polyethylene dome	100	NA	71	29
Wooden hutch	85	15	71	29

immunological state of the animal at blood sampling. Leukocyte counts are high at birth and in young calves (12). Erythrocyte counts in calves decrease gradually until reaching adult levels at 1.5 to 3 yr of age (4).

No differences were noted among housing types for hay and grain intake, girth, BW, and height. Jorgenson et al. (14) and McKnight (17) reported outside versus inside housing for calves had no effect on growth rate. According to observations of activities (from 0700 to 1900 h) at wk 1, 4, and 7, calves spent more time outside their hutches and standing (Table 5). Standing behavior of calves included eating and investigating housing; lying behavior included sleeping and ruminating. Calves spent similar amounts of time lying and standing, regardless of housing type.

CONCLUSIONS

For neonatal (1 to 8 wk) dairy calves, no differences were noted in feed intake, growth, blood measures, physiology, and behavior in the three housing types tested. Based on these comparisons during fall, the choice of calf housing can reflect manager preferences and economic considerations. The outdoor pens of the wooden and polymer hutches provided space for exercise, facilitated observations of the calves, and encouraged outside urination and defecation, thereby keeping hutches cleaner.

Commercially available temperature data loggers with thermistor sensors were used to evaluate tympanic temperatures in the calves. Maximum tympanic temperatures generally occurred from 1200 to 1800 h, and minimum tympanic temperatures occurred between 0600 to 0900 h. Objective classification of amounts of stress in the calves, based on fractal analysis of tympanic temperatures, indicated that stress decreased as age increased. More definitive determination of the circadian body temperature rhythms and verification of the stress boundaries of young calves should provide a basis for using these rhythms as a reliable indicator of physiological stress and should facilitate the assessment of stress response and help to identify ways to improve environmental management.

ACKNOWLEDGMENTS

Appreciation is expressed to Lisa Hollist and Elizabeth Howery for technical assistance in data acquisition, Kaye Hamilton for manuscript preparation, and Diane Purcell for fractal computations.

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